International Gas Union Research Conference 2014

Development of New Model Residential PEMFC micro-CHP Systems

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1. Abstract

Tokyo Gas started to sell an apartment buildings model of residential PEMFC micro-CHP system "ENE-FARM" in April 2014 for the first time in the world. This paper describes our successful development of the new system which meets various requirements for apartment buildings installation with maintaining the world's highest total efficiency of 95.0% in residential fuel cell CHP systems.

In addition, we developed optional units that enable ENE-FARM to continue generation in the event of grid power outage. One is for "survival" and continuing limited power supply during power outage by grid independent operation (Option A) and the other is for not only "survival" but also enabling start-up of ENE-FARM combined with battery system (Option B). Option A was released in April 2014 and Option B will be launched in October 2014.

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2. Introduction

2.1. Development and sales history of ENE-FARM

Tokyo Gas has been developing residential PEMFC (Proton Exchange Membrane Fuel Cell) micro-CHP systems with Panasonic Co. from 1998. After “the Large Scale Demonstration Project” (2005-2008) conducted by NEF (New Energy Foundation) / NEDO (New Energy and Industrial Technology Development Organization) and supported by METI (Ministry of Economy, Trade and Industry), Tokyo Gas released its first commercial model of a residential PEMFC micro-CHP system in 2009 by the name of “ENE-FARM” that is a common trademark in Japan. The second-generation model was released in April 2011, followed by a third iteration in April 2013. Each new release has brought performance, installability, and cost improvements, and a total of 30,000 units had been sold as of April 2014, which is the top share in Japanese whole sales value of 80,000.

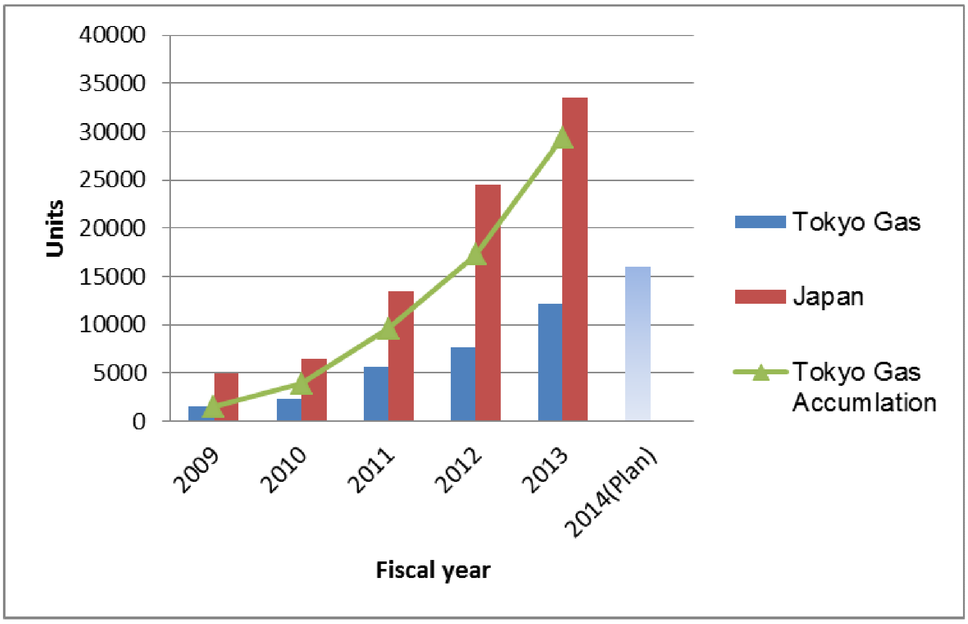


Fig 1: Sales results and plan of ENE-FARM

2.2. Motivation for the new model and options development

While sales growth to date has been promoted by government subsidies, further cost reductions will be needed to be achieved through efficiencies of scale if ENE-FARM sales are to really launch. Characteristically in the urban area in Japan, homes in apartment buildings are growing in larger proportion as shown in Table 1. To broaden the potential market, therefore, Tokyo Gas decided to develop and market a new model, based on its detached houses model, that would be installable in apartment buildings as well as detached dwellings as to date.

A public demand for greater energy security to counter concerns about supply continuity in the wake of the 2011 earthquake and outages caused by lightning strikes, typhoons, heavy snow, and other meteorological events is growing. In order to meet the public demand, the decision was also taken to develop and market an optional power continuity switch and power supply to allow electricity to continue to be generated in the event of a power outage.

Table 1: Amount of new houses construction in 2013

Place	Detached households	Apartment households	Total
Japan	597,222 (60%)	390,032 (40%)	987,254
Tokyo met.	54,652 (37%)	93,326 (63%)	147,978
Kanagawa pref.	36,389 (47%)	40,970 (53%)	77,359

Calculated using residence statistic report by the Ministry of Land, Infrastructure, Transport and Tourism, Japan

3. Development of apartment buildings model of ENE-FARM

3.1. Specifications

A typical installation image of the new model ENE-FARM is shown in Figure 2, and its specifications are compared with those of the conventional model (for detached houses) in Table 2. The power output and efficiency of the two models are the same. The user interface of color remote controller, which is also the same as that of the conventional one, is shown Figure 3. Note that the new model offers improved wind and earthquake resistance, making it better suited to be installed in apartment buildings, where there exist greater installation constraints than in detached houses.

Fig 2: Image of ENE-FARM installed in a pipe shaft of apartment buildings

Table 2: Specifications of apartment buildings model and detached houses model of ENE-FARM

		Apartment buildings model	Detached houses model (conventional)
Performance	Power generation output	200W-750W	←
	Electrical efficiency	39.0%LHV / 35.2%HHV	←
	Heat recovery efficiency	56.0%LHV / 50.6%HHV	←
	Overall efficiency	95.0%LHV / 85.8%HHV	←
	Tank capacity	147L	←
	Wind resistance	30m/sec	15m/sec
	Earthquake resistance	1.0G	0.4G
Dimensions	Fuel cell unit	H 1750mm W 399mm D 395mm	H 1850mm W 400mm D 400mm
	Hot water storage unit	H 1850mm W 560mm D 400mm	←
Weight (dry)	Fuel cell unit	99kg	90kg
	Hot water storage unit	54kg	55kg

(a) (b)

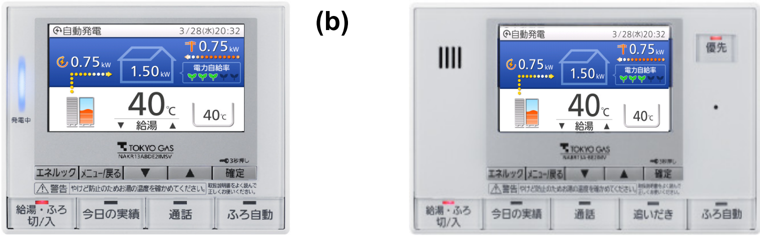


Fig 3: User interface of remote controller for (a) kitchen, and (b) bathroom

3.2. Advantage of new model

(1) Installable in pipe shafts

Design improvements including more gastight units and thicker external paneling materials allow the fuel cell unit, hot water storage unit, and backup boiler to be installed in pipe shafts facing onto open passageways. The fuel cell unit's exhaust and other ports have also been combined into one, allowing installation in pipe shaft access hatches, and the fuel cell unit and backup boiler now look more integrated when arranged side by side. One instance is shown Figure 4.

(a) (b)

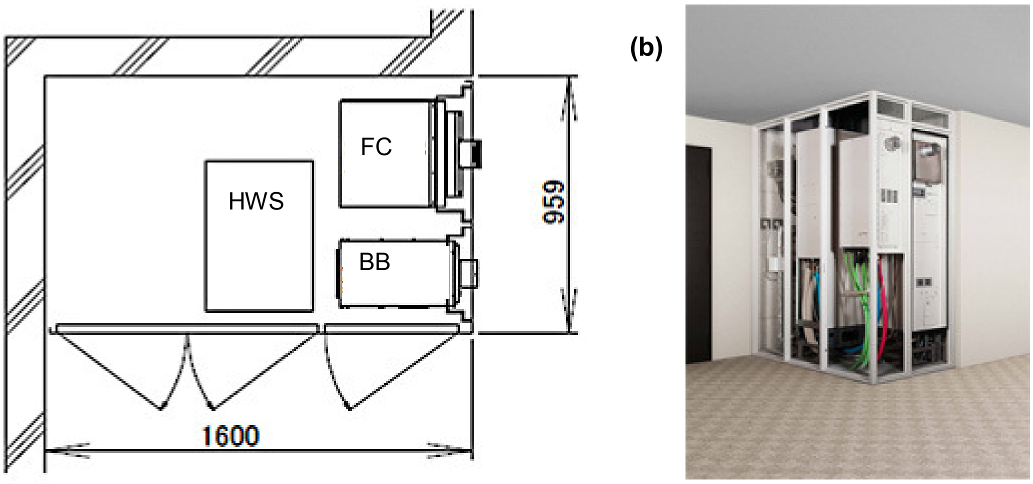


Fig 4: An Example of (a) installation layout and (b) an external view of ENE-FARM installed in a pipe shaft

(2) Complies with requirements for apartment installation

Earthquake resistance has been enhanced by strengthening the legs anchoring the units in order to meet building installation requirements. Then ENE-FARM have borne for 1G, compared the old model borne for 0.4G.

The design has also been made more wind resistant by bundling the fuel cell unit's air feed and exhaust ports together and mitigating the effects of wind pressure on the internal components, as shown in Figure 5, allowing the system to operate even in 30 m/s winds so it can be installed in high-rise buildings too.

(a) (b)

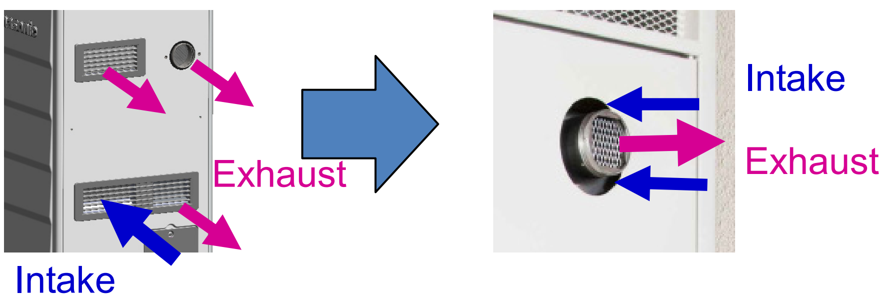


Fig 5: Construction of intake/exhaust: (a) conventional model, and (b) new model

(3) Suited to variety of installation configurations

As well as installing the fuel cell unit, hot water storage unit, and backup boiler together in one pipe shaft, the three units can also be located separately in different shafts. By providing multiple exhaust options for the fuel cell unit and backup boiler, and also offering a slim-type backup boiler as well as a standard one, the system can be installed in various kinds of ways in apartment buildings.

4. Development of optional units for power outage

4.1. Specifications

We developed two types of optional units which can be adapted to ENE-FARM and serve in the event of a grid power outage. Appearances of these devices are shown in Figures 6 and 7, and also their specifications are summarized in Table 3.

One, named “Option A”, has a switch unit which enables ENE-FARM to continue generating and supplying electricity to the home via an emergency outlet in the event of a power outage. This functionality is provided by a device that automatically switches the generated power feed from the distribution board during normal use to emergency outlets in an outage.

The other type, “Option B”, has been developed in order to start up ENE-FARM that is not generating in the event of a power outage. This option is composed of a switching unit and a power supply unit. In addition to the function that automatically switches the generated power feed from the distribution board during normal use to identified outage use, this option supplies necessary power to the sleeping ENE-FARM for starting up the Fuel cell unit of ENE-FARM (black out start, BOS).

Table 3: Specifications of two types of optional units for power outage

		Option A	Option B
Parts description	Unit name	Switching unit	(1) Power supply unit (2) Switching unit
	Dimensions / weight	H325×W485×D155 / 13kg	(1) H350×W605×D155 / 20kg (2) H325×W485×D155 / 14kg
	Installation location	Indoor wall-mounted	←
Performance	Continuing FC generation	○	←
	Starting up FC	×	○
	Max. inverter output on grid power outage	FC : 750W	FC : 750W Power supply unit : 500W (1000Wh capacity)
	Max. available power on grid power outage	Approx. 700W	Approx. 1200W
	Approx. supply duration on grid power outage	Max. 4 days (96hours) from start of generation before outage	Load until 700W : Max. 4 days from start of generation before outage Load until 900W : Max. 10 hours Load until 1200W : Max. 2 hours
	In outage, power supply to	Emergency outlet Hot water storage unit Back up boiler	Usual identified outlet Hot water storage unit Back up boiler
Retail price		JPY 130,000	(1) JPY 472,000 (2) JPY 143,000

(With front panel closed)　　　　　　　　　　　　　　　(With front panel open)

Front　　　　　　　　Side　　　　　　　　Front

Fig 6: Appearance of Option A

(a) Power supply unit

(With front panel closed)　　　　　　　　　　　　　　　(With front panel open)

Front　　　　　　　　Side　　　　　　　　Front

(b) Switching unit

(With front panel closed)　　　　　　　　　　　　　　　(With front panel open)

Front　　　　　　　　Side　　　　　　　　Front

Fig 7: Appearance of Option B (a) Power supply unit (b) Switching unit

4.2. Operation

(1) During normal use

In order to function, ENE-FARM needs power from the grid at startup and also to make up the shortfall in homes that consume more electricity than the system can provide. During normal use, therefore, ENE-FARM supplies power to the home via the distribution board in combination with grid power by tracking the electrical demand and using the voltage and frequency of grid power for its reference voltage. The flow of electricity during normal use and power outage of Option A and Option B are shown in Figures 8 and 9, respectively. In Option A, electricity does not flow to the emergency outlet, while in Option B, it flows to the identified outlet. The Power supply unit of Option B is also charged but never supplies power to the other loads.

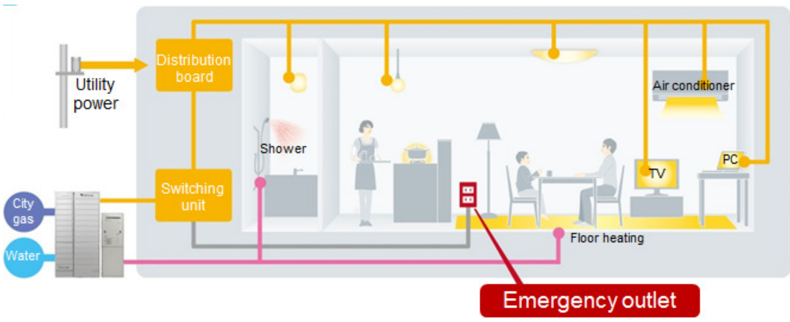
(2) During power outage

When ENE-FARM is in operation at the event of grid power outage, it survives from shutdown and continues power generation, if it equips either Option A or Option B. The power continuity switch in the options bypasses the distribution board and feeds power generated by ENE-FARM directly to the emergency outlets (by Option A) or identified outlets (by Option B). Examples of the home appliances that can be powered by ENE-FARM in grid power outage include LED lights, chargers for mobiles phones, gas appliances such as water heaters and floor heating systems.

When ENE-FARM is NOT in operation at the event of grid power outage, ENE-FARM can start up and supply power if it equips Option B. ENE-FARM is able to start autonomously by receiving power supply from the lithium ion battery built-in the Power supply unit. Note that you can use only emergency light during starting-up process of ENE-FARM until it starts power generation.

Electricity
Hot water
Electricity from emergency outlet

(a)Normal



(b) Power outage

Fig 8: Electricity flow of ENE-FARM with Option A at (a) normal and (b) power outage condition

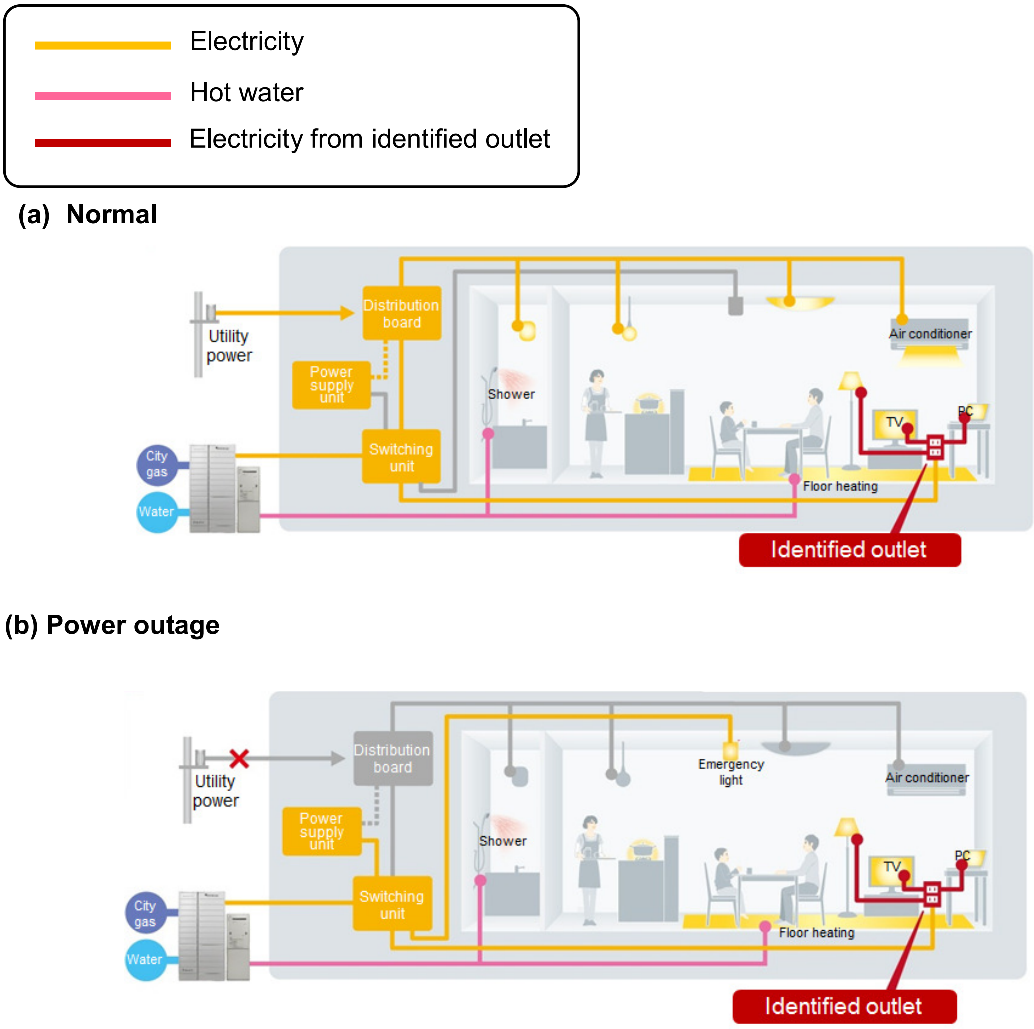


Fig 9: Electricity flow of ENE-FARM with Option B at (a) normal and (b) power outage condition

5. Summary

In order to expand the potential market of ENE-FARM, we developed apartment buildings model of ENE-FARM by means of modifying the conventional model for detached houses such as on wind and earthquake resistance, so that it can be installed in the apartment buildings including high-rise ones that are commonly built in the urban area. The system was released in April 2014.

Optional units which enable ENE-FARM to continue generating electricity during a power outage were also developed to meet customer needs. Option A was released in April 2014 and Option B will be launched in October 2014.

In fiscal 2014, Tokyo Gas aims to sell 16,000 units, up approximately 30% from 12,000 in fiscal 2013, of which 500 are projected to be orders for ENE-FARM systems for apartment buildings. Development will continue to be pursued in order to further expand ENE-FARM's adoption and so contribute more to protecting the global environment and stable energy supply.

6. Acknowledgement

Our deepest appreciation goes to METI, NEDO and NEF for their continuous support to development and introduction of ENE-FARM.